# Teaching Physics as a Non-specialist: the in-service training of science teachers

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ABSTRACT *Secondary teachers may be required to teach outside their specialist areas, either because of shortages of suitably qualified teachers or as a result of curriculum reorganisation. In the UK, the shortage of qualified physics teachers and the move towards balanced science courses result in many non-specialists teaching physics. A survey of 250 science teachers (non-physicists) shows significant differences between the difficulty anticipated in teaching many physics topics and that actually experienced. The findings suggest that in-service physics education for science teachers should be school-based, and grounded in a constructivist model of teachers' learning in science.*

## INTRODUCTION

In the United Kingdom, as in many other countries, there is a persistent problem of attracting enough entrants with qualifications in physics, mathematics and technology into teaching. External influences make the problem more or less acute at any particular time but the general picture of shortage is a long-standing one. The extent of the shortage in England and Wales has been spelt out in a recent Department of Education and Science (DES) paper *Action on Teacher Supply in Mathematics, Physics and Technology* (DES, 1986). In this article I shall be discussing the situation as it relates to the teaching of physics only.

One dimension identified in the DES paper is the so-called 'hidden shortage'—the teaching of substantial parts of the physics curriculum in many schools by teachers without formal qualifications in physics. Many of these are teachers qualified in another science subject (usually chemistry or biology) who are called upon to teach physics, either as a separate subject or as a component of a science course. Some of this work, particularly the teaching of science in the early years of secondary education, is now widely established as a normal part of the science teacher's job.

The introduction of a new system of national examinations for 16-year old school students (the General Certificate of Secondary Education, GCSE) has coincided with a rapid trend towards the adoption of broad and balanced science

courses (DES, 1985; SSCR, 1987) rather than courses in the separate sciences. This has greatly increased both the level and the extent of teaching outside their specialist disciplines which many teachers either find, or anticipate finding, themselves having to do. Both of these factors, then, the overall shortage of qualified physics teachers and the move towards teaching science rather than the separate sciences, give rise to a need for in-service education to help non-physics-qualified teachers to cope with the teaching of physics. Whilst this need may be widely recognised, little is currently known about what teachers themselves perceive as their priorities for professional development; about where those currently teaching physics experience difficulties; about the precise nature of the difficulties which others, facing the prospect of more physics teaching, anticipate. Nor has there been much discussion of the learning strategies and approaches which might constitute good practice in subject-specific in-service teacher education (INSET) of this kind.

## THE SURVEY

### *Aim*

The aim of the research study reported here, which was carried out during February and March 1987, was to obtain information from school science teachers, without formal qualifications in physics, about their perceptions of the difficulties in teaching physics; and hence to identify priorities for in-service education. The survey used a postal questionnaire, followed up by a small number of one-to-one interviews to amplify and clarify issues emerging in the questionnaire response.

The questionnaire sought information in five main areas:

(i) the qualifications and physics teaching experience of the respondents;
(ii) their perceptions of the difficulty of specific physics topics;
(iii) their views on the difficulty of specific teaching approaches, methods or skills in the teaching of physics;
(iv) their confidence in the use of specific pieces of physics apparatus;
(v) their views on the sort of in-service education in physics which they would welcome.

The design of the questionnaire had to take account of the wide variety of current physics teaching experience of the respondents. Most were likely to have taught some physics to pupils in the 11–13 age range; many could be expected to have taught physics as part of a science course to 13–16 year olds (particularly to pupils of lower ability); fewer were likely to have taught physics as a separate subject to 14–16 year olds. So the questionnaire sought to distinguish between the difficulty which teachers had *experienced* in teaching physics topics and the difficulty which they might *anticipate* in looking to the sort of physics topics they might be required to teach in the future.

The questions were of both open and closed formats, giving 'check lists' of topics, methods and apparatus to remind respondents of the range of possibilities, but also providing space for free responses, both to permit amplification of responses to the more structured elements of the question and to cover the

possibility of items important to the respondent having been omitted from those listed.

### *Implementation*

Following initial contacts, questionnaires were sent out in batches of 10 with a covering letter to Heads of Science departments in 100 secondary schools in the North of England. The sample comprised all secondary schools within a chosen geographical area, selected to provide a representative mix of rural, suburban and urban schools. A covering letter asked the Head of Science to pass questionnaires on to all the teachers in the science department without formal qualifications in physics. Questionnaires were returned from 73 schools, providing 245 questionnaires for analysis. In addition to the information obtained from the questionnaire survey, nine interviews were conducted with teachers in three schools. These were tape recorded and transcribed.

## TEACHERS' VIEWS ON PHYSICS TEACHING

### *Qualifications and experience*

The respondents divided fairly evenly into biology and chemistry specialists (see Table I). Only two teachers claimed to have taught no physics to pupils in any part of the 11–16 age range. Experience of teaching physics as part of a science course is widespread, particularly in the 11–13 age range where over 77% have done so. The percentages reporting experience at some time in teaching physics *as a separate subject* at the 11–13, 13–14 and 14–16 stages are 21%, 41% and 41% respectively. These substantial percentages may give an indication of the extent of the physics teacher shortage in the survey region. Of the 245 teachers, 177 had some experience of teaching physics in some form to pupils in the 14–16 age range.

### *Physics topics*

The questionnaire provided information about topics which the respondents had experience of teaching and those which they had found difficult or would anticipate finding difficult. The topics most commonly identified as difficult fell into a small number of well defined areas of physics: electronics and the cathode-ray oscilloscope headed the list, followed by electromagnetism and current electricity, with mechanics and quantitative work on heat also identified as problematic. These results are scarcely surprising but are rather a confirmation of what might have been expected. They indicate that electricity (including electromagnetism and electronics) and mechanics are clear priorities for in-service education. What may be more significant is to compare the rank orderings of difficulty anticipated by teachers who have not taught a topic and the difficulty experienced by those who have. The differences between the two rankings are displayed in Table II. In general, far more

TABLE I. (a) Qualifications and (b) physics teaching experience of the teachers in the survey sample

| (a) Subject | No. of teachers |
|---|---|
| Biology | 97 |
| Chemistry | 105 |
| Biology/chemistry | 25 |
| Other | 18 |
| | 245 |

*Others included Craft, Design and Technology, Mathematics, Science, Horticulture, Art and Design, Geology, Geography, Geography and Primary Science.

| (b) Teaching experience | To pupils aged 11–13 | To pupils aged 13–14 | To pupils aged 14–16 |
|---|---|---|---|
| Physics as a separate subject | 54 | 100 | 100 |
| Physics as part of a science course | 190 | 126 | 139 |

Of the 245 teachers 177 had had experience of teaching physics in the 14–16 age group. Two had not taught any physics.

teachers anticipate difficulty with most topics than appear to experience it. It is particularly noticeable that electronics topics feature much more prominently in the 'anticipated as difficult' list, whilst the mechanics topics are higher in the list of 'experienced as difficult', as are some of the more fundamental electricity concepts such as potential difference (voltage). Detailed teaching packages for electronics teaching may have made this topic more straightforward than teachers expect. On the other hand, for some conceptually difficult topics (like mass and weight, and voltage), the difficulty of teaching may become more apparent when faced with actually having to teach it! Topics involving calculation and formula-handling also tend to be higher in the rank order of experienced difficulty.

This question of differences between 'anticipated' and 'experienced' difficulty is perhaps worth pursuing a little further. For many topics, the difference between the percentage of teachers who have not taught the topic but would anticipate difficulty and the percentage of teachers who have taught the topic and experienced difficulty, is statistically significant at the 1% level, using a chi-square test on a $2 \times 2$ contingency table for each topic. From the point of view of in-service education planning, this is surely worth noting. Supporting teachers adequately during their first experience of tackling a new physics topic may be a particularly effective means of altering their perception of its difficulty. Conversely, we may suppose that a bad first experience may be very damaging to a teacher's confidence in tackling further topics.

TABLE II. Physics topics anticipated and experienced as most difficult (in rank order)

| Anticipated as difficult | Number of teachers | Experienced as difficult | Number of teachers |
|---|---|---|---|
| 1. Transistor | 63 | 1. Voltage | 31 |
| 2. Diode | 62 | 2. Electromagnetic induction | 30 |
| 3. Electronic logic gates | 60 | 3. Specific heat capacity | 26 |
| 4. Cathode-ray oscilloscope | 57 | 4. Latent heat | 25 |
| 5. Transformer | 36 | 5. Mass and weight | 20 |
| 6. Electromagnetic induction | 32 | 5. Series and parallel circuits | 20 |
| 7. Dynamo | 31 | 7. Acceleration | 19 |
| 8. Electric power | 28 | 7. Forces and motion | 19 |
| 9. Ohm's Law | 25 | 7. Inertia | 19 |
| 9. Circuit calculations | 25 | 10. Density | 18 |
| 9. Inertia | 25 | 10. Dynamo | 18 |
| 12. Equations of motion | 24 | 10. Water waves | 18 |
| 13. Electrical resistance | 23 | 10. Ray diagrams | 18 |
| 14. Calculating fuse values | 22 | 14. Electric current | 17 |
| 14. Potential energy calculations | 22 | 14. Cathode-ray oscilloscope | 17 |
| 16. Kinetic energy calculations | 20 | 14. Microscope and telescope | 17 |
| 16. Half-life | 20 | 17. Electrostatics | 16 |
| 16. Voltage | 20 | 17. Circuit calculations | 16 |
| 19. Electrostatics | 19 | 19. Ohm's Law | 15 |
| 19. Radioactivity | 19 | 19. Gas Laws | 15 |
| 21. Velocity-time graphs | 17 | 19. Diode | 15 |
| 22. Acceleration | 16 | 19. Transistor | 15 |
| 22. Forces and motion | 16 | 19. Electronic logic gates | 15 |

Some respondents used the open-response questions to amplify their answers. Many of these responses pointed to teachers' uncertainties about their own conceptual grasp of ideas and about their own learning difficulties:

> I do not feel happy about voltage, amps, etc. Probably because I have not spent sufficient time on them. I always feel as if I haven't the key to the subject securely in my mind.

> ... the problem is basically, there's certain subjects which I've always sort of been wary of, for example, some of the things related to electricity...

These and many similar comments referred to teachers' *confidence* in their knowledge and understanding, an issue which will be taken up again in the next section.

### *Teaching methods and skills*

The purpose of the section of the survey dealing with teaching methods and skills was to encourage respondents to consider whether there were some types of classroom activity which they found difficult to manage and sustain *when teaching*

*physics*. There are some indications from the research literature that differences between specialist and non-specialist teachers may be more noticeable in terms of classroom approaches and teaching 'style' than in terms of conceptual understanding. Hacker & Rowe (1985), using a detailed science classroom observation schedule, categorised teachers' styles as informer, enquirer or problem-solver. They observed 12 physics specialists and 12 biology specialists teaching both physics and biology topics and found:

> substantial changes in teaching and learning processes when the topics studied were outside the teacher's specialist discipline area. ... informational approaches were twice as likely to be encountered when the teacher was teaching outside his discipline area and this increase was at the expense of more effective problem-solving and enquiry approaches.
>
> (p. 173)

The findings of this survey point in a similar direction (Table III). Project work and open-ended investigations were identified as particularly difficult, though more (apparently) in anticipation than in the event. Answering pupils' questions is generally identified as a difficulty. Comments from questionnaires and from interviews show that much of this difficulty is associated with teachers' breadth of background knowledge and with their confidence in that knowledge. Those cited below are a small selection from among a considerable number of similar comments.

TABLE III. Teaching methods and skills seen as difficult

| | Anticipated as difficult | Experienced as difficult | Total |
|---|---|---|---|
| Explaining theoretical ideas | 7 | 17 | 24 |
| Question and answer sessions | 4 | 14 | 28 |
| Pupil physics practicals | 1 | 5 | 6 |
| Doing physics demonstrations | 4 | 18 | 22 |
| Relating physics to everyday applications | 3 | 16 | 19 |
| Project work in physics | 42 | 2 | 44 |
| Open-ended physics investigations | 46 | 4 | 50 |
| Answering pupils' questions about physics | 27 | 23 | 50 |

*On project work and open-ended investigations:*

> Difficult—I haven't enough background. I would find these difficult because of my own lack of confidence.
>
> In some topics would find this difficult due to lack of breadth/depth of physics knowledge.
>
> Not secure enough in my own knowledge. I don't know enough!

> I don't possess sufficient depth of knowledge.

*On answering pupils' questions:*

> Not enough 'background' knowledge.
>
> Difficult—I haven't enough background. I would find this difficult because of my own lack of confidence.
>
> I do not have the grounding in physics.
>
> Lack of depth of own knowledge and being 'one stage ahead' sometimes a problem.

Not surprisingly, this issue of the depth and extent of background knowledge needed for effective teaching arose many times in interviews:

> I have not got the confidence to expand on anything more than what's in front of me, and I sort of worry about it because I sit down and feel I spend a long time learning it and making sure I've got it all right and I've got all the facts and I haven't missed anything out, and then teach it. And I feel if somebody asks me a question, I can sort of cope with a small bit of expansion of what I've taught and then after that, you know, I'm struggling. And I feel that's not fair on them.
>
> I'm just honest with them. If I don't know anything and they ask me, I say I will go and ask A. [Head of Science—a physicist], and come back to them . . . I feel unsure, not problems discipline-wise, but knowledge-wise . . . if I haven't got the in-depth knowledge, I feel I might teach it them in a muddle.
>
> There's two problems. Explaining something, like potential difference, trying to put that across. And then when you're teaching a subject, even though you've understood the main bit, they can ask you all sorts of questions on the outside, you know, something they've seen outside, and they can just go, 'Ay, you know, what about that?', and that can stump you, that little outside.
>
> I don't feel I've got the sort of background, the anecdotes, and the little sort of stories you build up, when it's a sort of a specialist subject.
>
> I have to go to a colleague and say 'Would you like to suggest how I can extend this person in this particular area?'. I don't find any problem at all with what I've called average and below-average, but I don't think it's fair on the brighter kids if I can't provide the extension.

These matters—of background familiarity with a subject, of having a fund of stories and anecdotes, of confidence in one's depth and breadth of knowledge, of the ability to recognise which pupils' questions and difficulties are genuinely difficult (where the teacher can admit that s/he doesn't know) and which are more straightforward (where the teacher might be expected to know)—are the products of extensive experience, rather than of short-course provision. Yet they appear to be close to the nub of teachers' own perceptions of where their expertise falls short. In designing appropriate provision for these teachers' professional development, we need to recognise this as an important area where there are unlikely to be any easy solutions.

### *Apparatus*

Many non-specialist teachers speak of difficulties in handling certain items of physics apparatus in the classroom. This part of the survey sought to identify those items of physics apparatus which pose particular difficulties for the non-specialist. Again, a striking feature of the responses is that difficulty is anticipated by a much higher percentage of those teachers who have not used each item of equipment than is experienced by those who have—for *all* the pieces of apparatus mentioned. In many cases, the difference is again statistically significant at the 1% level.

In open responses, teachers wrote of 'lack of confidence' and 'lack of experience' as leading to difficulty with the pieces of equipment they had identified. The cathode-ray oscilloscope has a particularly high difficulty rating. It is seen as having 'complicated instructions'; some users "can never get the controls adjusted"; it is "difficult to set up when [you] only use [it] occasionally". Similar comments also apply to other apparatus. Ripple tanks are perceived as "unreliable for good results" and "take a great deal of time to set up to observe what pupils are supposed to see". The van de Graaff generator is 'temperamental', as are circuit boards. In general, the items of physics apparatus with which non-specialist teachers lack confidence are those which are seen as *complex* (number of controls to set, number of connections to make, long and detailed instructions to follow) or *unreliable* in producing the 'correct' results in the classrooms. INSET might address this by providing hands-on experience with a range of different versions and models of these 'difficult' pieces of apparatus. This, together with some greater understanding of what the instruments do (and, therefore, of what the apparently complex controls are for), might go some way to increasing confidence in using the equipment in the classroom.

Another separate group of comments about physics apparatus deals with *safety*. Several respondents wrote of their concerns about the safety of radioactive sources: "scared of them—safety"; "need to be refreshed fully on safety factors"; "I realise that the sources are not dangerous but I feel uneasy about how to handle them". Safety is also an issue when high voltage supplies are in use. One teacher reported "worry about safety aspects of electricity"; another asked about the van de Graaff generator "is it really safe to use on (sic) children?" Again hands-on experience would seem to be the only means of alleviating these concerns. Issues of safety of

apparatus may need to be addressed directly and explicitly in a programme of physics in-service education.

## IN-SERVICE PHYSICS EDUCATION FOR TEACHERS

### *Non-specialists' Views on Physics*

In looking to the contribution which non-specialist teachers might make to the teaching of physics in the secondary school, it is salutory to be reminded of these teachers' own perceptions of their physics knowledge and their attitude to the subject. Many of those interviewed saw themselves as having a very low baseline of physics background knowledge.

> I'm a classic non-physics. I went to an all-girls school and you didn't do physics and chemistry... we did it up to third-year and that was it.

> All the way through school I avoided physics. I always had a thing about it, I didn't even do it in first and second year... I've never done anything at all... I just avoid it like the plague. Now I feel I haven't got the confidence to cope with it by myself.

For some teachers, particularly biology specialists, there may be what one referred to as 'a backlog of rejection' of physics, stretching back to school days. One significant influence is often teachers' own experience of learning physics as a school pupil. In talking of teaching forces and motion and electricity, one teacher commented:

> You see I don't really feel a yen to teach those things... that's why I chose to teach biology. Maybe it was my early physics teaching, you know, the person who taught me, but I didn't find it particularly interesting at the time.

> My own experience of physics is of being badly taught... being pushed into O-level with half the syllabus missing.

One consequence of this is that a surprising number of non-physicists seem to see physics, not as a coherent body of knowledge, but as a collection of discrete bits:

> When you do biology, it all hangs together, because you are doing about the body, which is one *thing*. But when you do physics, you're dealing with different phenomena, sections, topics...

Although easily overlooked, this may be of some importance in designing in-service physics education for teachers. It seems clear that many teachers of biology and chemistry have *actively* opted out of physics at an earlier stage in their careers. For some, the reasons lie in part in poor teaching or in restrictive subject choices. Others have simply not found physics interesting. They may, indeed, never have had a feeling for what physics is about. So instead of seeing physics as concerned with

some basic and fundamental questions about how the physical world behaves (which might be of general interest and value), they see it as a collection of diverse and unrelated bits of knowledge. A major challenge for in-service physics education may be to provide non-specialist teachers with an overview of physics as a subject—with the grand picture before tackling the fine detail. As one teacher remarked:

> If you said to me, what do I think about physics, I would say to you, 'I think it is boring'. Now if a child said to me, 'I think it is boring' about biology, I'd hit the roof. Now I'm only saying to you exactly what a child would say to me, therefore . . . I need to have in me an interest in physics generated . . . my interest needs to be stimulated.

### *Informal in-service Education*

Perhaps we should begin by asking the question: to what extent is *formal* in-service education required? How far can teachers be expected to broaden their knowledge base through self-study using existing materials? Several of the teachers interviewed discussed their efforts to brush up their physics knowledge in different ways:

> I've tried these books *Teach Yourself Physics* . . . I just get bowled over by the terminology. I've been fairly successful with other subjects, but I just can't cope with the physics. I feel there's so many bits and pieces of words to learn, and everybody's telling me it's easy and I find it hard . . .

> [Teaching yourself from a textbook] takes a great deal of time. It's the same as me giving the kids a textbook and saying, get on and teach yourself. . . . Bearing in mind the sort of pressures that are on us, to give us a textbook and expect us to work from that, I mean, we just won't do it.

Alongside these individual efforts at self-improvement, several teachers pointed to the value of co-operative work within departments to help non-specialists. This goes on in many schools, though it is often fitted into odd minutes during breaks and lunch hours. Adequate *time* is frequently not available. One teacher commented that it was . . .

> . . . generally felt within the department that *internal* INSET time would be most valuable. [respondent's emphasis]

Another talked during an interview about the availability of help from colleagues:

> If I don't understand, I would quite happily hop along to one of the physics teachers and say . . . will you just go over this and sort it out for me. But the time's limited for that . . . when we're actually free to do it. I dare say if we had unlimited free time, we could solve the whole problem . . .

*A School Focus*

Teachers in general tended to take the view that some formal in-service physics education would be welcome and, indeed, necessary if they were to teach the new GCSE science syllabuses effectively. Many expressed in general terms their need for courses to 'build up confidence' and to 'broaden background knowledge'. The essential criteria for in-service physics education, in many teachers' responses, are that it should be closely linked to the realities of practice, knowledgeable about new syllabuses and their emphases, realistic about the situation in schools as regards staffing, technician support and the quality and quantity of equipment, supportive of informal in-school structures for helping the non-specialist.

There was a widespread feeling that any formal in-service education would be more effective if it were school-based or school-focused in some way. For some, this meant formalising the co-operative work already going on in schools and (importantly) allocating time within the working week to it:

> School based INSET . . . in the form of workshop sessions. These could be run by the physics specialists on the staff.

> Observing good experienced physics teachers teaching their own subject.

> I could do with time in my own school with the physics staff so I would be familiar with equipment we have. It would need to be a regular time, say a double period each week if I were teaching a new area.

For others, a school focus could include 'working with imaginative teachers', whether from their own school or another, or with staff from teacher training institutions. A number of interesting course formats were suggested:

> I don't feel that one-off courses, or weekends on their own tend to be an awful lot of good . . . I think self-help groups are the sort of things, on a fairly frequent basis . . . maybe even if the self-help group could plan a series of activities.

> . . . a course, I think, to actually prepare a topic and use the expertise of other physicists . . .

> If you had some sort of course where you'd got a number of teachers approaching the same topic . . .

> If you're preparing [a topic] for yourself, you want to be confident . . . if you're not sure exactly how far a particular topic should go, then, you know, you're struggling. So maybe working in a group of people doing that, you know, when you've got somebody who can give you guidelines . . . if there were a few—a small number—of you, you'd get more out of it really . . .

> ... to actually get a group of people [i.e. non-specialist teachers] together to prepare a topic ... put their expertise together, discuss it, come up with a decent module ... and do the same thing with every physics topic they are likely to cover ... ironing out difficulties ... you'd have to have the expertise from a physicist, wouldn't you?

A possible model here is, perhaps, a course provided by an external agency for a group of teachers from one school, or a number of schools in a local consortium. Part of the course would involve teachers working in small groups, preparing a teaching sequence for a physics topic, and then discussing their schemes with the whole course group. Topics would be selected on the basis of their centrality to the science courses followed in the schools.

An advantage of a course of this sort is that it could provide a vehicle for integrating the learning of physics concepts and the development of pedagogical skills for teaching these concepts to students. Many comments in the survey indicate, either implicitly or explicitly, a concern on the part of teachers not only to understand physics content and ideas, but also for help in teaching them to others.

### *In-service Physics Education: content*

The survey indicated strongly that in-service physics education needs to start at a very basic content and concept level. Typical descriptions of what was wanted were:

> Courses in basic physics topics, assuming no knowledge of the topic, on modern teaching methods of the particular topic.

> A very basic course on physics—starting where the students would ... and going through current Integrated Science syllabus.

> Something to help me get my facts clear from scratch all about basics of physics.

These are just a few chosen from many similar comments. It is clear that, in terms of content and concepts, in-service physics education should assume a very low baseline and take each topic to the level required by the syllabuses.

As a means of providing formal in-service education, there may be a significant role for individual (or group) self-study materials. Forthcoming distance learning materials (Open University, 1988) may offer a means of involving many more teachers in a systematic programme of professional development. The role of tutorial support in any courses based around such materials may, however, be as important as the materials themselves. Support from a tutor or other 'expert' seems necessary to overcome problems of concept understanding in certain areas and, perhaps more importantly, to help teachers overcome the barrier posed by their lack of confidence.

It also seems clear that, however it is provided, any formal in-service physics

education should function primarily as a support for the informal in-service education which is already going on in many school science departments.

## CHILDREN'S (AND TEACHERS') LEARNING IN SCIENCE

For many non-specialist teachers, learning physics topics will involve conceptual change—coming to understand physics concepts differently. In-service courses are vehicles for promoting this development, for instigating conceptual change. There is a large and growing body of science education literature dealing with children's learning of science concepts and with concept change in school children (Driver, Guesne & Tiberghien, 1985; Osborne & Freyberg, 1985; West & Pines, 1985). We know that the 'mental models' which non-expert adults form of many scientific ideas and situations differ from those of experts in much the same way as do children's ideas (Gentner & Stevens, 1983). This work on children's learning can provide guidelines for the design of learning activities for adults.

As one teacher interviewed commented:

> ... if you could teach me in the same way I would teach ... the children, that would help me ...

In practice that would mean adopting the best currently available concept learning model—the *constructivist*, or *generative learning* model—in designing in-service physics education for teachers (Driver & Oldham, 1986; Osborne & Wittrock, 1985). This would recognise that non-specialist teachers *do* have some ideas about most physics concepts in the syllabuses, though some of these ideas may well differ from the accepted ones. If courses are to succeed, they need to take account of these prior ideas. For each topic, a starting point is to elicit teachers' current ideas and understandings about the topic. On the basis of this, they can then be directed to carefully chosen readings and practical activities, designed specifically to challenge or deepen existing ideas. The course structure would have to provide adequate opportunity to review ideas with an 'expert'. The next stage, of consolidation, could be achieved particularly well through the sort of group work on preparing teaching outlines and materials which some teachers suggested in the extracts cited above, or through problem-solving exercises. One project which has gone some way towards designing in-service education materials along these lines is the New Zealand Learning in Science Project (LISP). In the Teachers' Guides prepared to accompany units on the teaching of science concepts, an introductory section elicits and clarifies teachers' current understandings before going on to discuss how to teach the ideas to students (Osborne, Schollum & Hill, 1981).

Adopting this teaching and learning model for in-service physics education would involve breaking new ground, extending ideas about the teaching and learning of children to adult learners. A programme of in-service education adopting this framework would be, to that extent, an innovation. Yet there are good grounds, both in the state of our current understanding of children's learning of science, and in the views of non-specialist teachers expressed in response to the various elements of

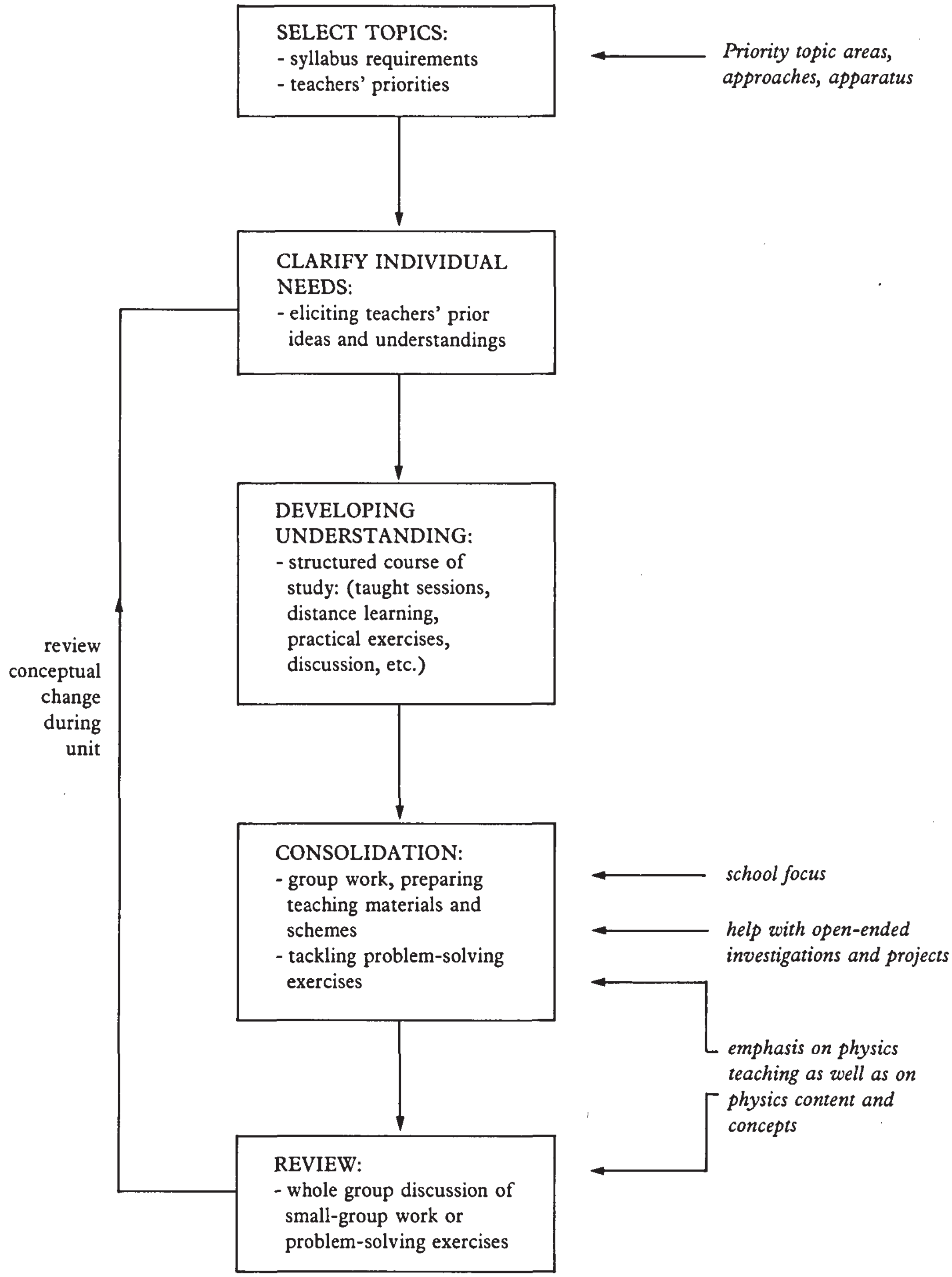


FIG. 1. Physics for the non-specialist teacher: a constructivist model for in-service education

this survey, to suggest that the development and evaluation of such a program would be a worthwhile undertaking.

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